Minor Elements in Nakhlite Pyroxenes: Cr in MIL00346. **G**. A. McKay[1], C. Schwandt[2], L. Le[2], J. Makishima[3], T. Mikouchi[3], and T. Kurihara[3], [1]Mail Code KR, NASA Johnson Space Center, Houston, TX 77058, [2]ESC Group, NASA Johnson Space Center, [3]Dept. of Earth and Planetary Science, Univ. of Tokyo, 7-3-1 Hongo, Tokyo 113-0033, Japan.

Introduction: Nakhlites are olivine-bearing clinopyroxene cumulates [e.g., 1]. Based on petrographic characteristics, they may be divided into groups that cooled at different rates and may have been formed at different depths in a single flow [e.g., 2, 3]. The order of cooling rate from slowest to fastest is NWA998<Lafayette < Governador Valadares ~ Nakhla < Yamato000593 < NWA817 ~ MIL03346. Nakhlite cumulus pyroxene grains consist of large cores that are nearly homogeneous in major element composition surrounded by thin rims that are zoned to Fe-rich compositions. Detailed study of these pyroxenes is important because they retain a record of the crystallization history of the nakhlite magma. Moreover, because the composition of the nakhlite parent melt cannot be directly determined, “inversion” of the major and minor element composition of the cumulate pyroxene cores can be used to estimate the composition of that melt. Thus it is important to understand the major and minor element zoning in the cumulus pyroxenes. While major elements are nearly homogeneous, minor elements exhibit distinctive zoning patterns that vary from one nakhlite to another [e.g., 3,4]. This abstract reports unusual Cr zoning patterns in pyroxenes from MIL03346 (MIL) and contrast these with pyroxenes from Y593.

Minor Element Zoning: Nakhlite pyroxenes are zoned in Al, Ti, and Cr. Al and Ti are strongly correlated, but Cr is not correlated with these elements. Pyroxenes from slowly cooled nakhlites generally exhibit a bimodal zoning pattern for Al and Ti, but rapidly-cooled sample MIL has a single mode of Al concentrations (Fig. 1) [3]. The origin of this zoning is not completely understood. However, by analogy with pyroxenes from our experimental runs, we believe that it is likely produced by sector zoning during growth.

In contrast, Cr in slowly cooled samples exhibits only minor Cr zoning, but rapidly-cooled MIL pyroxenes are strongly zoned in Cr (Fig. 3). Cr is depleted in the central portions of the pyroxene grains, but enriched in the outer portions of the homogeneous cores, and then strongly depleted in the Fe-enriched outer rims. Cr zoning is not correlated with Al zoning. Except for the outer Fe-enriched rims, this zoning pattern is in marked contrast to that expected during normal fractional crystallization. Typically, early-formed, central portions of crystals are enriched in Cr and outer portions are depleted because Cr is a highly compatible element in olivine, pyroxene, and spinel, and is thus depleted from the melt during the course of crystallization, leading to decreases in Cr from core to rim. In contrast, MIL

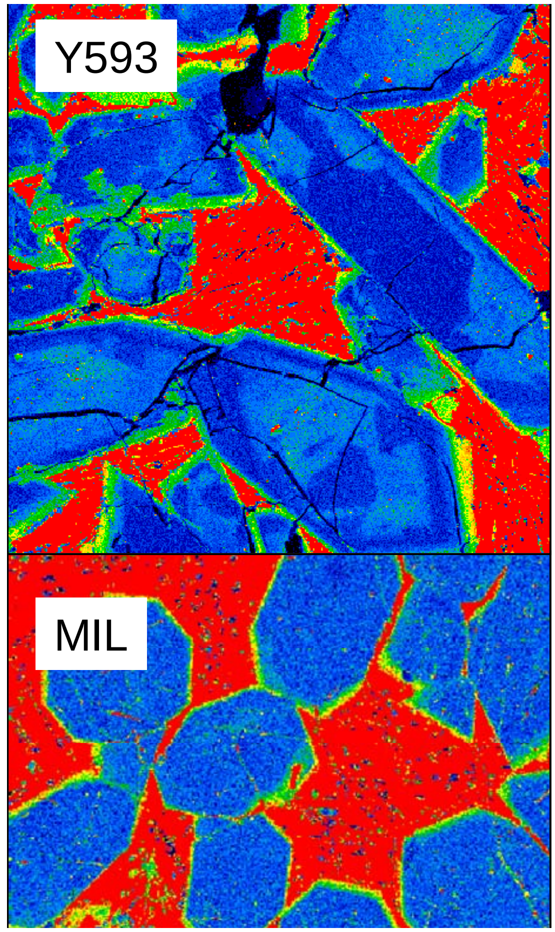

Fig. 1. Al maps of Y593 and MIL. Field of view is about 2 mm. Note patchy zoning in Y593, typical of zoning in slowly cooled nakhlites, and lack of zoning in MIL.

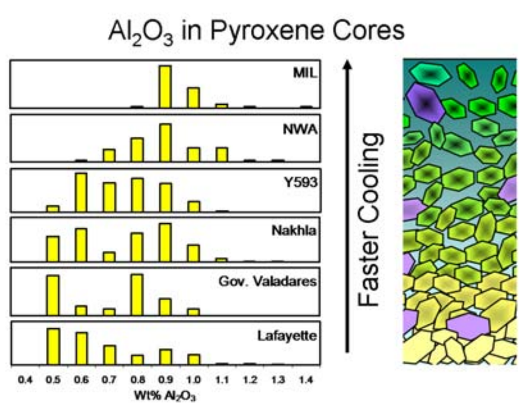

Fig. 2. Histograms of Al content in nakhlite pyroxenes, arranged according to estimated cooling rates [2].

pyroxenes exhibit an abrupt increase near the outer portion of the homogeneous core, then show the expected depletion in the late-stage Fe-enriched outer rim (Fig. 3).

Discussion. The source of the unusual Cr zoning is difficult to understand. Fractional crystallization would be expected to produce the opposite pattern, i.e. Cr depletion from core to rim. One possibility is that the Cr zoning might reflect a change in oxidation state of the magma during crystallization of the pyroxenes. Average D(Cr,Px/L) in our experiments increases by nearly a factor of 3 as oxygen fugacity increases from IW to QFM (Fig. 5). This probably reflects the ease of charge balancing in the presence of increased amounts of Fe^{+3}. MIL has been reported to have large amounts of trivalent Fe compared with other nakhlites [5,6]. Whether this effect is responsible for the unusual zoning in MIL is yet to be determined.

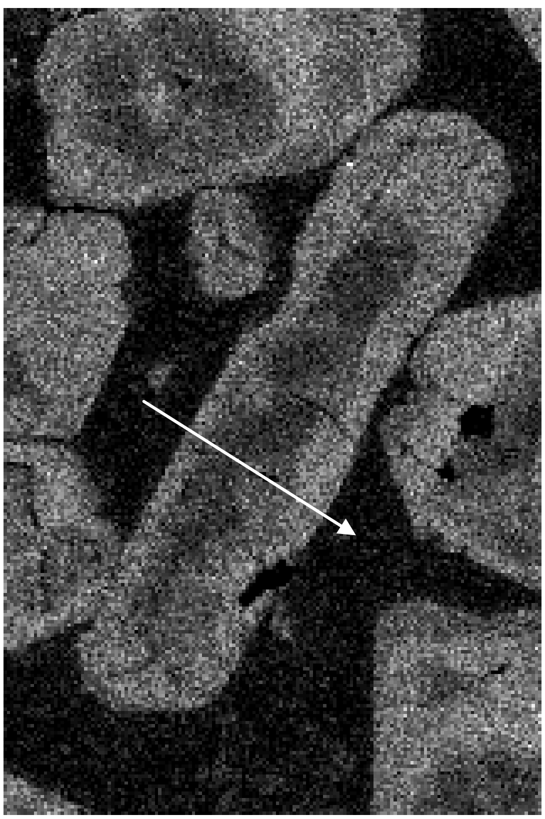

Fig. 3. Cr map of MIL pyroxenes. Note Cr depletion in center of grains relative to margin. Cr-enriched portion is outer part of core that is homogeneous with respect to major elements. Arrow shows location of microprobe profile in Fig. 4.

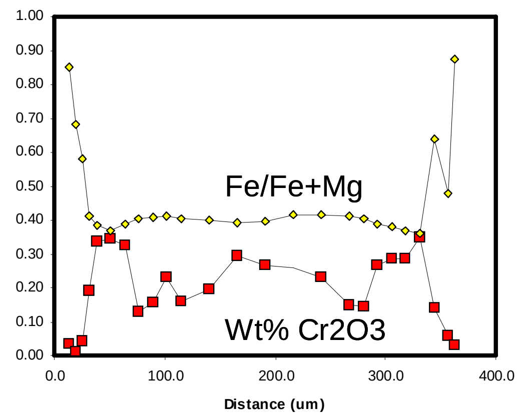

Fig. 3. Microprobe profiles across MIL pyroxene in Fig. 3. Note that Cr enrichment is within homogeneous core (constant Fe/Fe+Mg).

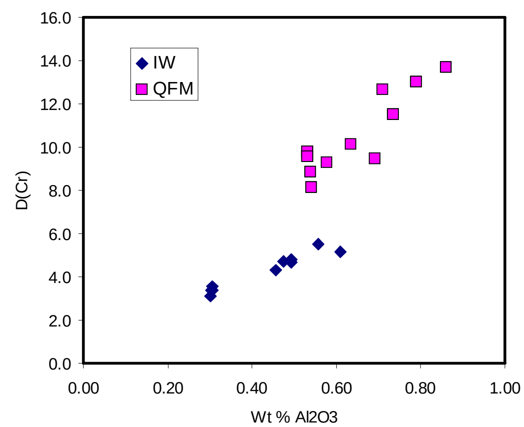

Fig. 5. Pyroxene/melt partition coefficients from nakhlite crystallization experiments. Note that average D values increase from ~4 to ~12 as oxygen fugacity increases from IW to QFM.

References: [1] Wadhwa (2001) Science 291, 1527. [2] Mikouchi *et al.* (2006) LPSC 37, #1865. [3] McKay *et al (2005), MAPS 40, 5335*. [4] McKay *et al.* (2006) LPSC 37, #2435. [5] Morris *et al.* (2006) LPSC 37, 1594. [6] Dyar M.D. et al. (2005) *JGR, 110*, doi:10.1029/2005JE002426.